BENTON HARBOR POWER PLANT LIMNOLOGICAL STUDIES

PART XV: THE BIOLOGICAL SURVEY OF 12 NOVEMBER 1970

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INTRODUCTION

In Part VII (March 1971) of our report series relative to the Donald C. Cook Nuclear Station, we established the following report format:

A. COOK PLANT PREOPERATIONAL STUDIES

- A.1 Recording of Local Water Temperatures
- A.2 Study of Floating Algae and Bacteria
- A.3 Development of a Monitor for Phytoplankton (ABANDONED)
- A.4 Study of Attached Algae
- A.5 Study of Zooplankton
- A.6 Study of Aquatic Macrophytes
- A.7 Study of Benthic Organisms
- A.8 Study of the Local Fishes
- A.9 Support of Aerial Scanning
- A.10 Study of Entrainment and Impingement

B. SURVEYS OF EXISTING WARM WATER PLUMES

C. THE ICE BARRIER AT THE COOK PLANT SITE

D. EFFECTS OF EXISTING THERMAL DISCHARGES ON LOCAL ICE BARRIERS

E. EFFECTS OF RADIOACTIVE WASTES IN THE AQUATIC ENVIRONMENT

- E.1 Gamma Scan of Bottom Sediments (FINISHED)
- E.2 The Most Sensitive Organism for Concentration of Radwastes (FINISHED)
- E.3 Study of Lake Michigan's Present Radioactivity Content (FINISHED)

This report covers only items A.2, A.5, and A.7 of the above format. These studies constitute a survey of the large-scale set of biology stations related to the Donald C. Cook Plant carried out on 12 November 1970.

The layout of sampling stations, with indication of how the stations are numbered, is given in Figure 1. The sampling stations, their positions relative to the Cook Plant, their distances offshore, and the water depths encountered are given in Table 1 and Table 1A.

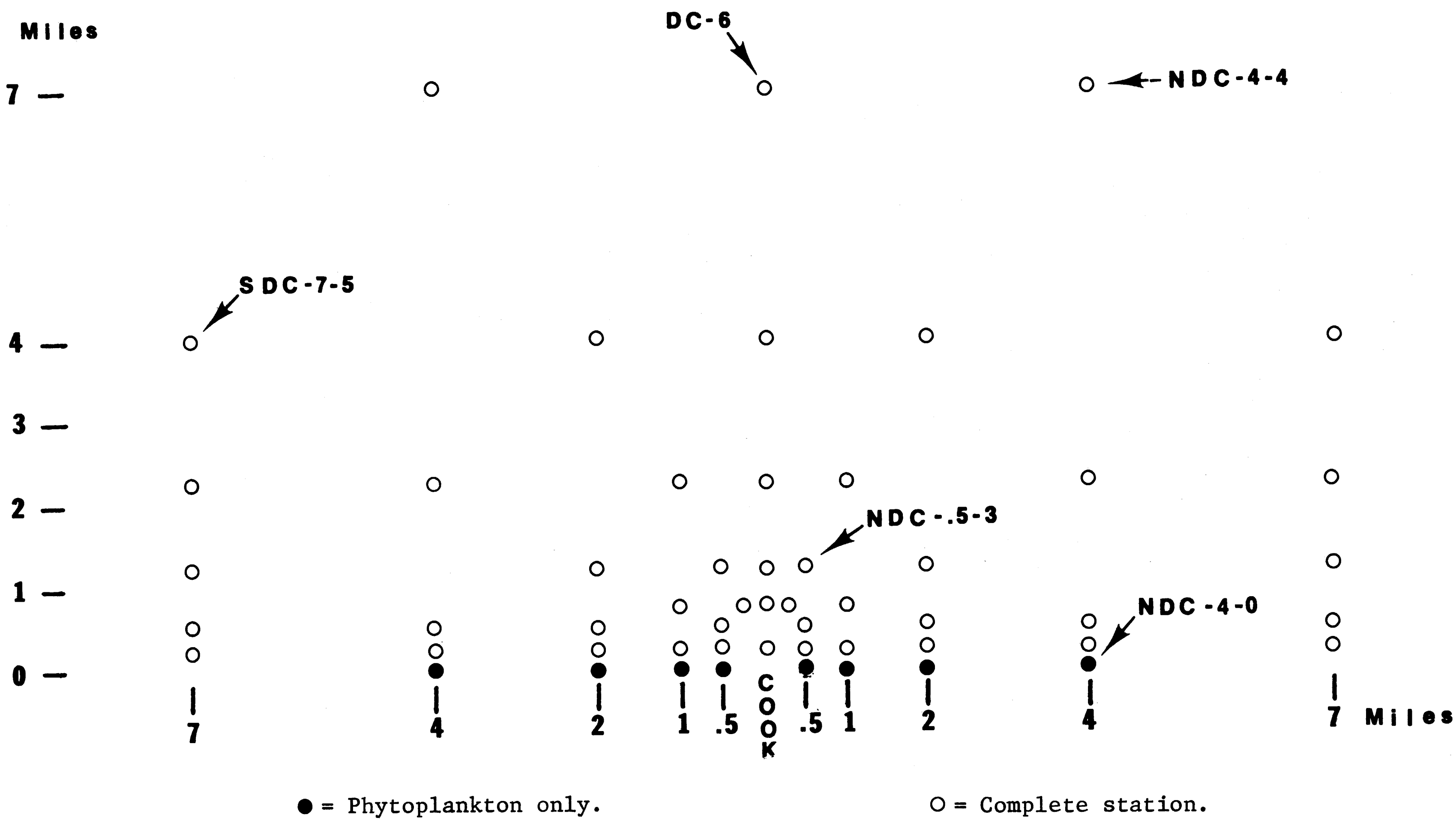

Figure 1. The Cook Plant sampling stations. The stations are designated as follows: SDC stations are located south of the Donald Cook Plant, NDC stations are north of the plant, and the DC stations are directly offshore. The first number in the designation is the number of miles north or south of the plant. The second number is the serial number of the station. The serial number of the phytoplankton-only stations is 0.

Table 1. The sampling stations, their positions relative to the Cook Plant, their distances offshore, and the water depths encountered on 12 November 1970.

Station	Position relative to the Cook Plant	Water Depth (ft)
DC-1	Directly off the plant, 1/4 mi offshore	*
DC-2	" " " " 3/4 " "	45.5
DC-3	" " " " 1 1/4 " "	55.5
DC-4	" " " " 2 1/4 " "	66.1
DC-5	" " " " 4 " "	79
DC-6	" " " " 7 " "	128
NDC-.25-1	1/4 mi north of the plant, 3/4 mi offshore	45
NDC-.5-1	1/2 " " " " " 1/4 " "	16.8
NDC-.5-2	" " " " " " 1/2 " "	30
NDC-.5-3	" " " " " " 1 1/4 " "	60
NDC-1-1	1 " " " " " 1/4 " "	20
NDC-1-2	" " " " " " 3/4 " "	29.2
NDC-1-3	" " " " " " 2 1/4 " "	67
NDC-2-1	2 " " " " " 1/4 " "	20
NDC-2-2	" " " " " " 1/2 " "	30.2
NDC-2-3	" " " " " " 1 1/4 " "	49.7
NDC-2-4	" " " " " " 4 " "	79.5
NDC-4-1	4 " " " " " 1/4 " "	18.6
NDC-4-2	" " " " " " 1/2 " "	30.7
NDC-4-3	" " " " " " 2 1/4 " "	60.5

*Station not occupied. Dredge working there.

Table 1 continued

Station	Postion relative to the Cook Plant	Water depth (ft)
NDC-4-4	4 mi north of the plant, 7 mi offshore	139
NDC-7-1	7 " " " " " 1/4 " "	19
NDC-7-2	" " " " " " 1/2 " "	27
NDC-7-3	" " " " " " 1 1/4 " "	46.5
NDC-7-4	" " " " " " 2 1/4 " "	54
NDC-7-5	" " " " " " 4 " "	76
SDC-.25-1	1/4 " south " " " 3/4 " "	44
SDC-.5-1	1/2 " " " " " 1/4 " "	19
SDC-.5-2	" " " " " " 1/2 " "	32.3
SDC-.5-3	" " " " " " 1 1/4 " "	52
SDC-1-1	1 " " " " " 1/4 " "	25.3
SDC-1-2	" " " " " " 3/4 " "	31.8
SDC-1-3	" " " " " " 2 1/4 " "	64
SDC-2-1	2 " " " " " 1/4 " "	14.8
SDC-2-2	" " " " " " 1/2 " "	30.4
SDC-2-3	" " " " " " 1 1/4 " "	53.5
SDC-2-4	" " " " " " 4 " "	74.6
SDC-4-1	4 " " " " " 1/4 " "	17.3
SDC-4-2	" " " " " " 1/2 " "	29.7
SDC-4-3	" " " " " " 2 1/4 " "	59.5
SDC-4-4	" " " " " " 7 " "	106.5
SDC-7-1	7 " " " " " 1/4 " "	20.2

Table 1 continued

Station	Position relative to the Cook Plant								Water Depth (ft)
SDC-7-2	7	mi	south	of	plant,	1/2	mi	offshore	30
SDC-7-3	"	"	"	"	"	1 1/4	"	"	50.6
SDC-7-4	"	"	"	"	"	2 1/4	"	"	55.1
SDC-7-5	"	"	"	"	"	4	"	"	70.5

Table 1A. Additional stations for phytoplankton only. (all in 4 ft. of water.)

Station	Position relative to the Cook Plant										
NDC-.5-0		1/2	mi	north	of	the	plant,	just	off	the	beach
NDC-1-0	1		"	"	"	"	"	"	"	"	"
NDC-2-0	2		"	"	"	"	"	"	"	"	"
NDC-4-0	4		"	"	"	"	"	"	"	"	"
SDC-.5-0		1/2	"	south	"	"	"	"	"	"	"
SDC-1-0	1		"	"	"	"	"	"	"	"	"
SDC-2-0	2		"	"	"	"	"	"	"	"	"
SDC-4-0	4		"	"	"	"	"	"	"	"	"

Phytoplankton samples were taken at all the stations of Table 1. At all stations with serial numbers greater than zero, zooplankton, benthos, and physical measurements were collected as well. The physical measurements consisted of surface water temperature, water depth, bottom types, Secchi disc water transparency, and water color as seen above the white 20-cm Secchi disc. Weather conditions and wind and wave characteristics were taken, and meteorological data taken on 12 November 1970 apply to all the sections of this report; these data are presented in Appendix A.

A.2 Study of Floating Algae and Bacteria

On the date of this survey, techniques for the determination of bacteria were being tried but usable results were not being obtained.

The phytoplankton collections of 12 November 1970 were collected and preserved with Utermohl's iodine fixative in our usual manner, but for reasons not known the collections disintegrated and were unusable.

A.5 Study of Zooplankton

Zooplankton Techniques

Zooplankton collections were made by a vertical haul, from bottom to surface, with a #5-mesh (0.282-mm average openings) net of .5-m diameter. A propeller-type flowmeter was affixed in the center of the net mouth to obtain quantitative measurement of the volume of water sampled by the net. The volume of water that passed through the net was indicated by the number of revolutions made by the flowmeter propeller; this figure was recorded and later converted to an equivalent expressed in liters of water.

The net was then raised above the surface and rinsed to free organisms impacted on the net and to concentrate the sample in the collecting jar tied on the narrow cod-end of the net. Then, excess water in the brimful jar was decanted through a small area of the net just above the cod-end. This small area of the net was then rinsed carefully to wash all zooplankters into the collecting jar with a minimum amount of water. The jar was removed from the net, and Koechies fixative, a solution of formalin and sugar, was added as a preservative. An identification label containing pertinent collection data was placed in the jar. The jar was capped and labeled exteriorly for delivery to the laboratory.

In the laboratory, the sample volume was measured by transferring the entire sample to a graduated cylinder. The entire sample then was returned to the collecting jar and mixed thoroughly and continuously with a magnetic stirrer while 1-ml subsamples were extracted with a Henson-Stempel pipette. Each subsample was placed in a depression in a clear glass spot plate. Each depression received a few drops of soap solution to break the surface tension

and allow the zooplankton to settle to the bottom for easier counting. A variable-magnification binocular microscope was used with transmitted light for counting and identification. As many 1-ml subsamples were counted as were necessary to obtain good statistical parameters. The number of zooplankton per liter of water was obtained by conversion with standard factors.

The #5 plankton net does not quantitatively collect the smaller crustacean species, and its use was abandoned after 1970; a #10 mesh net has been used since. The 1970 samples were enumerated by slightly different methods than those now in use, but both methods give comparable results. Samples counted earlier and recently recounted (given in Table 36 of Part XIII and repeated here as Table 2) agreed closely.

The qualitative composition of the November 1970 plankton fauna is illustrated by the species counts for stations DC-2 and DC-6 (Table 3). These were counted recently by current methods.

The November 1970 fauna resembled closely that reported for 1972. The absence of nauplii and *Tropocyclops prasinus* from these stations can be explained by the coarse mesh net used in 1970. We found no specimens of *Cyclops vernalis, Chydorus sphaericus,* or *Polyphemus peciculus,* but these species were rare or absent in November 1972 as well. In 1970, as in 1972, immature copepods were major components of the zooplankton assemblage (the 1970 counts are probably underestimates because of the loss of early instars through the net). But the two bosminid species, *Bosmina longirostris* and *Eubosmina coregoni* were more abundant in 1970, especially at the inshore station; evidently the autumn bosminid pulse lasted longer in 1970 than in 1972. In both years *Eubosmina* outnumbered *Bosmina* in November. In 1970, bosminids were the dominant zooplankters at all but a few offshore stations

Table 2. Comparison of zooplankton counts subsampled with a pipette (A) and the same samples subsampled with a Folsom plankton splitter (B) from station DC-6 on four dates in 1970 and 1971. Organisms per cubic meter.

	10 July 1970*		28 Sept. 1970*		12 Nov 1970*		15 April 1971**	
	A	B	A	B	A	B	A	B
Nauplii	***		***		***		***	
Cyclopoid copepodids	13,500	12,400	1,700	1,400	2,200	2,100	3,200	2,900
Diaptomid copepodids	5,000	4,800	12,000	10,400	8,800	8,100	1,600	2,100
Epischura			100	90	50	40		
Eurytemora		40		10	20	70		
Limnocalanus	20	10	500	300	20	40		
Bosminidae	4,600	4,420	1,900	1,600	2,000	1,700		
Ceriodaphnia	20	10	10					
Chydorus				10				
Daphnia	100	80	5,000	4,000	600	700		
Diaphanosoma			200	100	10	30		
Holopedium			10	40	30	40		
Leptodora			80	40		10		
Polyphemus	400	200						
Asplanchna	50	60	400	300	10	60		
TOTAL	23,000	22,100	21,900	18,200	13,800	12,700	4,800	5,600

*Collected with #5 mesh net.

**Collected with #10 mesh net.

***Nauplii were not enumerated by the earlier methods.

Table 3. Zooplankton species counts (ind/m^3), coefficients of variation between duplicate subsamples, percent composition by species, total zooplankton weight (mg/m^3), and mean zooplankter weight (μg/ind) for 2 stations sampled on 12 November 1970.

SPECIES	DC-2			DC-6		
	#/m^3	c.v.	%	#/m^3	c.v.	%
Copepod nauplii	--	--	--	--	--	--
Cyclopoid copepods						
Immature copepodids	2,907	4	12.4	1,390	10	10.9
Cyclops bicuspidatus thomasi	1,147	3	4.9	661	0	5.2
Cyclops vernalis	--	--	--	--	--	--
Tropocyclops prasinus mexicanus	--	--	--	--	--	--
Calanoid copepods						
Immature copepodids	4,013	5	17.1	4,625	3	36.3
Diaptomus ashlandi	227	25	1.0	785	27	6.2
Diaptomus minutus	640	6	2.7	1,335	16	10.5
Diaptomus oregonensis	1,347	7	5.7	1,321	3	10.4
Diaptomus sicilis	13	144	0.1	28	0	0.2
Epischura lacustris	13	144	0.1	41	47	0.3
Eurytemora affinis	187	20	0.8	69	28	0.5
Limnocalanus macrurus	--	--	--	41	47	0.3
Harpacticoid copepods						
Canthocamptus sp.	--	--	--	--	--	--
Cladocerans						
Bosmina longirostris	2,120	20	9.0	399	5	3.1
Ceriodaphnia quadrangula	13	144	0.1	--	--	--
Chydorus sphaericus	--	--	--	--	--	--
Daphnia galeata mendotae	307	6	1.3	275	14	2.2
Daphnia retrocurva	453	8	1.9	372	16	2.9
Diaphanosoma leuchtenbergianum	--	--	--	28	0	0.2
Eubosmina coregoni	10,013	8	42.6	1,252	23	9.8
Holopedium gibberum	80	0	0.3	41	47	0.3
Leptodora kindtii	--	--	--	14	143	0.1
Polyphemus pediculus	--	--	--	--	--	--
Rotifers						
Asplanchna sp.	27	0	0.1	55	0	0.4
TOTAL	23,520			12,731		

where they were outnumbered by immature copepods. However, the percent composition estimates are based on totals which do not include the smaller forms included in subsequent surveys.

No gravid copepods were noted in these samples. Several of the cladoceran species gave evidence of fall breeding, however. Males of *Daphnia galeata mendotae*, *D. retrocurva*, *Diaphanosoma leuchtenbergianum*, *Holopedium gibberum*, and *Eubosmina coregoni* were noted, as were ephippial females of *Daphnia retrocurva* and both bosminid species.

The counts for the other stations (enumerated by the earlier method) are given in Table 4. We have also listed the diversity indicies calculated for each station; these are included for comparative purposes since this parameter was reported for earlier collections. These calculations are subject to the criticism that they are based on superspecific categories collected with size-selective apparatus. Other objections are possible as well. Recent authors (Hurlbert 1971; Hill 1973) have criticized the concept of the diversity index and questioned its usefulness as an ecological indicator. And the supposed relationship between "diversity" and "stability" in ecosystems remains to be demonstrated.

Total zooplankton numbers collected in November 1970 were roughly comparable to those found in 1972. A few stations near the plant site and south of it (circled in Figure 2) had abundances of over 30 individuals per liter. The spatial distributions of the three most abundant zooplankton groups on 12 November 1970 are summarized in Figures 2-5. Bosminids were concentrated near shore (Figure 3), where they usually numbered between 8 and 20 per liter; two inshore stations had over 50 per liter, and four had 5-6 per liter. All stations offshore of the heavy line in Figure 3 had less

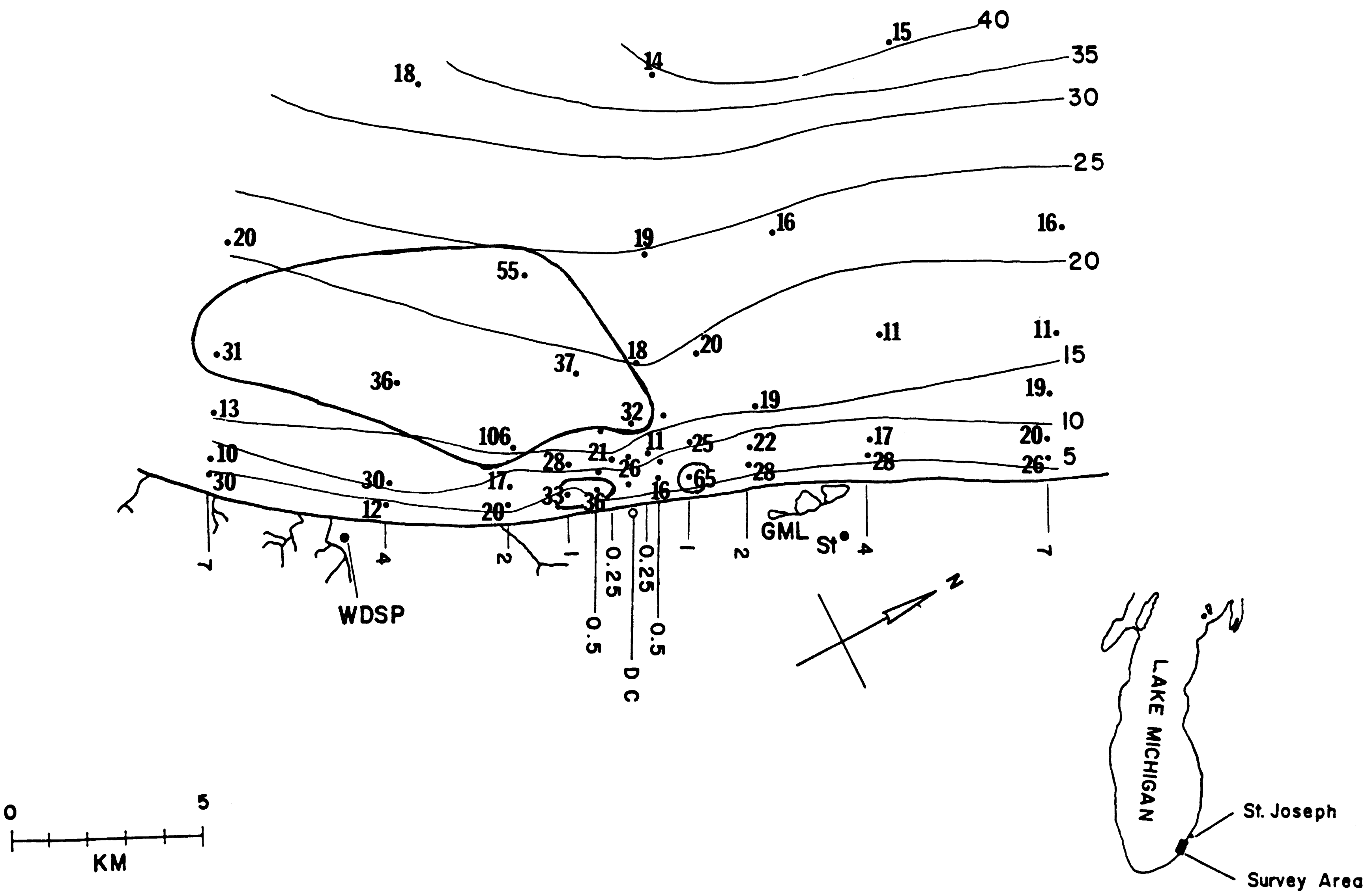

Figure 2. The spatial distribution of total zooplankton counts (individuals per liter) at 41 stations on 12 November 1970.

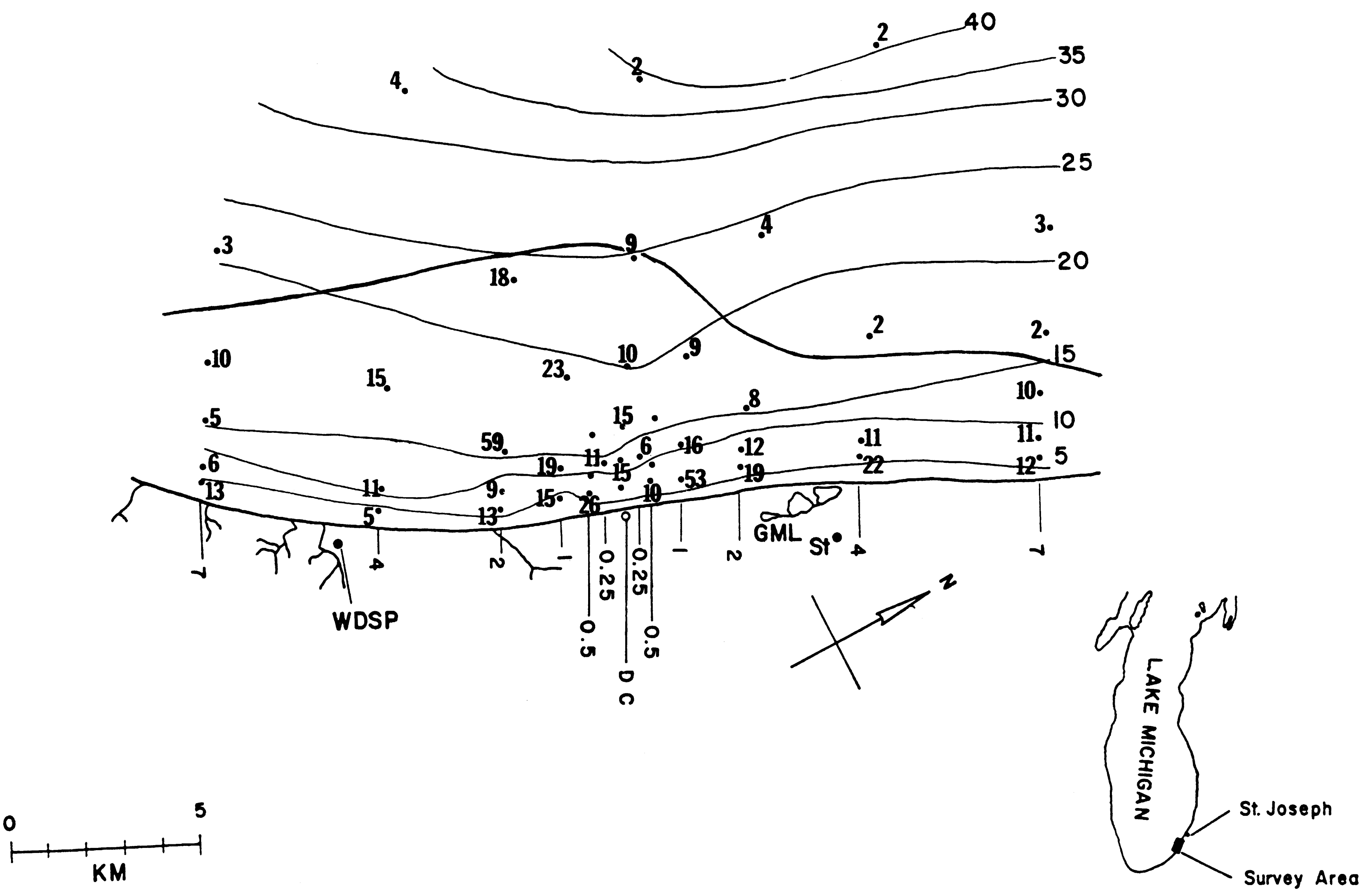

Figure 3. The spatial distribution of bosminids (individuals per liter) at 41 stations on 12 November 1970.

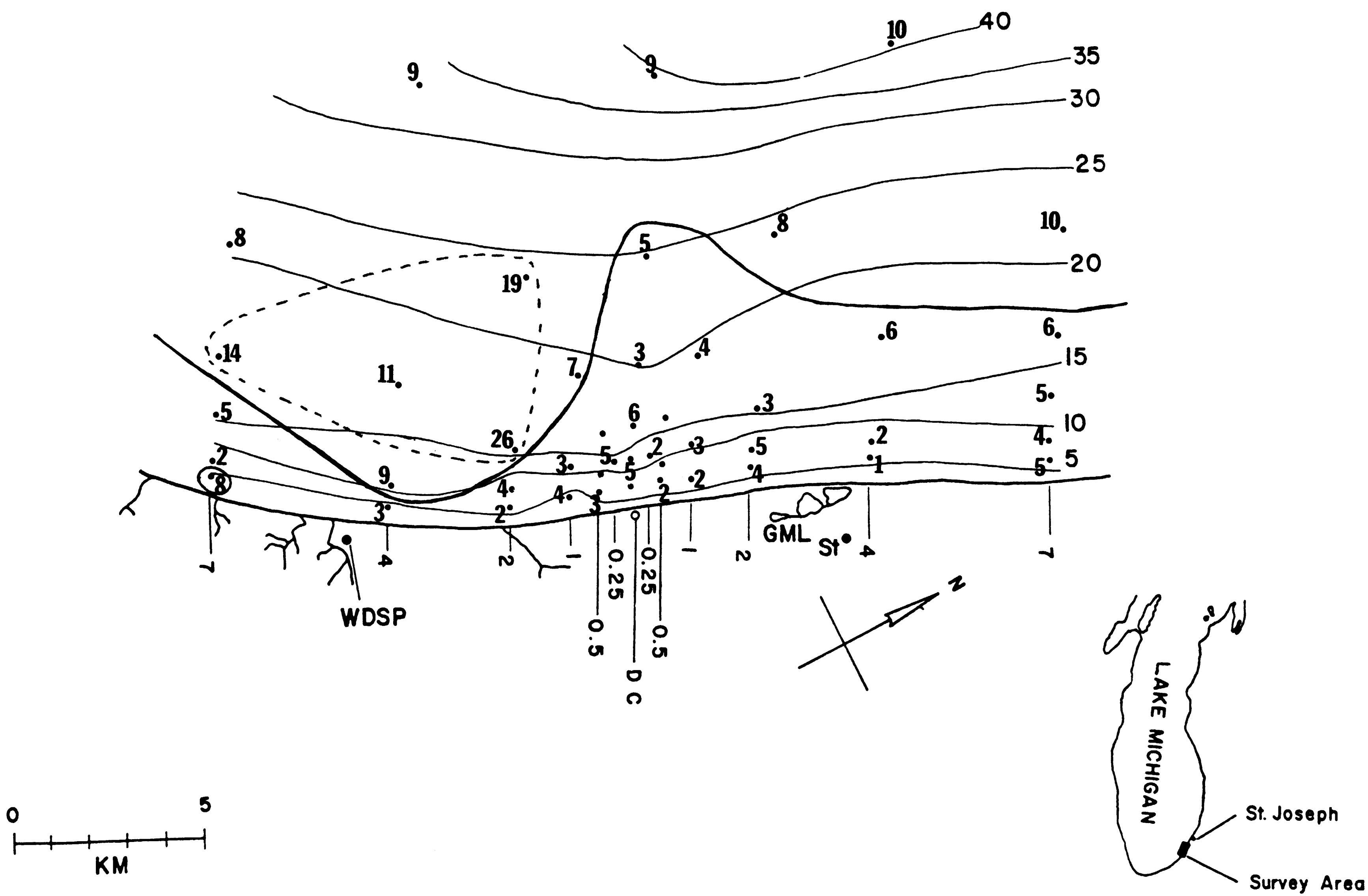

Figure 4. The spatial distribution of diaptomids (individuals per liter) at 41 stations on 12 November 1970.

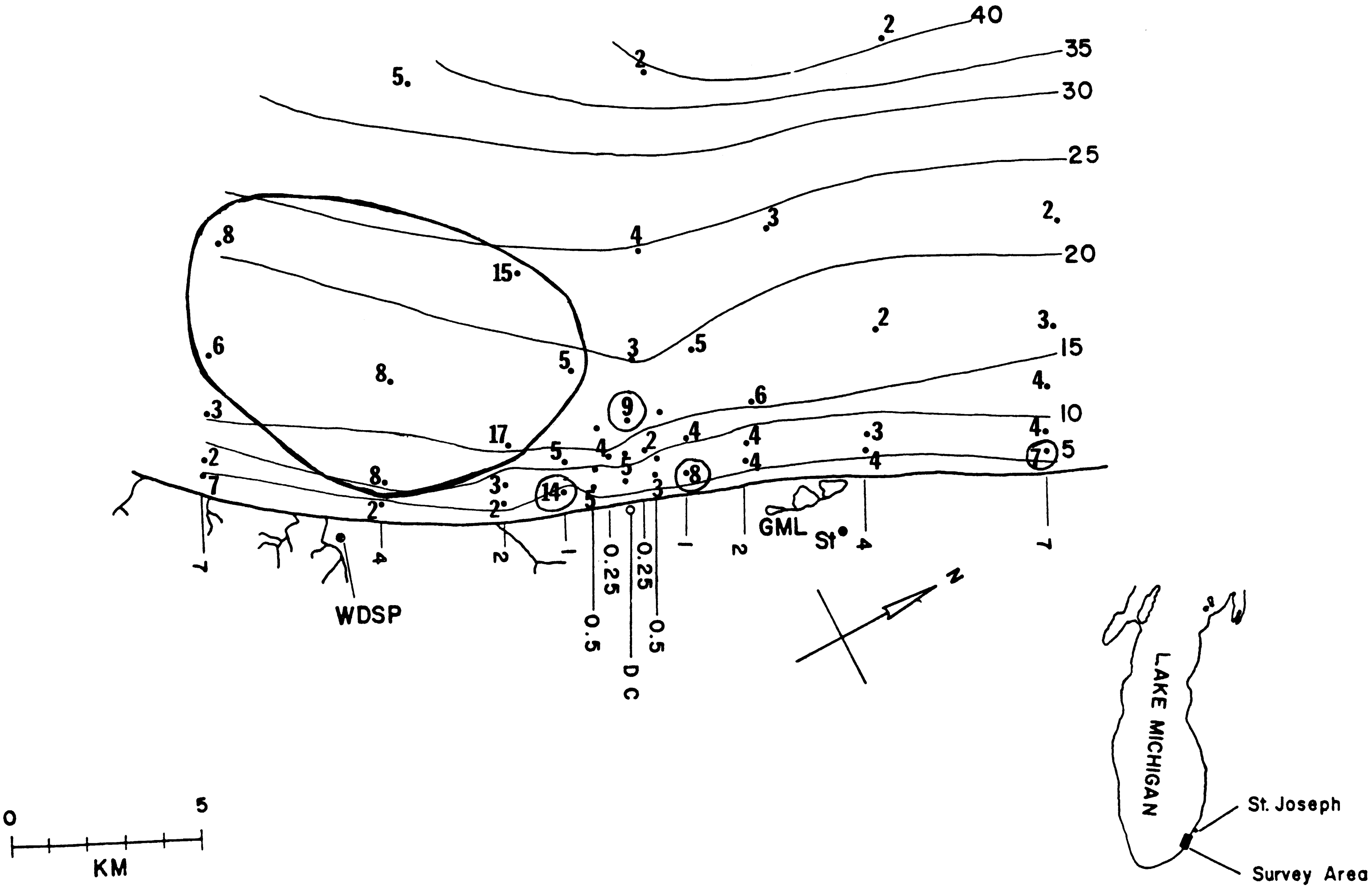

Figure 5. The spatial distribution of cyclopoids (individuals per liter) at 41 stations on 12 November 1970.

Table 4. Zooplankton, 12 November 1970. Samples by vertical haul of metered #5 Net. Organisms per liter.

Organisms	Stations					
	DC-1*	DC-2	DC-3	DC-4	DC-5	DC-6
Copepods:						
Diaptomids	--	5.34	6.05	3.31	4.61	8.81
Epischura	--	0.11	0.12	0.04	0.04	0.05
Eurytemora	--	--	0.08	--	--	0.02
Limnocalanus	--	--	--	--	--	0.02
Senecella	--	0.02	--	0.03	--	--
Cyclopoids	--	4.57	8.73	3.09	4.04	2.18
Harpactacoids	--	0.02	--	--	--	--
Cladocerans:						
Alona	--	--	--	--	--	--
Bosmina	--	14.99	15.22	10.06	9.13	2.00
Ceriodaphnia	--	--	--	0.01	--	--
Daphnia	--	0.97	1.12	0.79	0.59	0.64
Diaphanosoma	--	0.07	0.11	--	--	0.01
Eurycercus	--	--	--	--	--	--
Holopedium	--	0.15	0.21	0.17	0.08	0.03
Leptodera	--	0.04	0.03	0.01	0.03	--
Polyphemus	--	0.04	--	--	--	--
Rotifers:						
Asplanchna	--	0.04	0.08	0.04	0.03	0.01
TOTAL		26.36	31.75	17.55	18.55	13.77
Diversity index		1.70	1.81	1.69	1.72	1.53

*Station not occupied, dredges on the position.

Table 4 continued

Organisms	Stations NDC-.25-1	NDC-.5-1	NDC-.5-2	NDC-.5-3	NDC-1-1
Copepods:					
Diaptomids	2.40	1.76	*	*	2.27
Epischura	0.06	0.04	*	*	0.06
Eurytemora	0.11	0.02	*	*	--
Limnocalanus	0.04	--	*	*	--
Senecella	0.04	--	*	*	--
Cyclopoids	1.84	3.06	*	*	8.35
Harpactacoids	--	--	*	*	--
Cladocerans:					
Alona	--	--	*	*	--
Bosmina	6.20	10.06	*	*	52.71
Ceriodaphnia	--	--	*	*	--
Daphnia	0.44	0.65	*	*	1.23
Diaphanosoma	0.02	0.02	*	*	--
Eurycercus	0.02	--	*	*	--
Holopedium	0.06	0.10	*	*	0.32
Leptodera	--	0.01	*	*	--
Polyphemus	--	--	*	*	--
Rotifers:					
Asplanchna	0.01	0.02	*	*	0.26
TOTAL	11.24	15.74			65.20
Diversity index	1.80	1.53			0.98

*Sample broken

Table 4 continued

Organisms	Stations NDC-1-2	NDC-1-3	NDC-2-1	NDC-2-2	NDC-2-3	NDC-2-4
Copepods:						
Diaptomids	2.98	3.86	3.61	4.85	3.23	7.66
Epischura	0.03	0.04	0.03	--	0.06	0.10
Eurytemora	0.02	0.11	--	0.03	0.14	--
Limnocalanus	--	0.01	--	--	--	--
Senecella	--	0.10	--	--	0.02	--
Cyclopoids	4.36	4.82	3.81	4.45	6.18	3.08
Harpactacoids	--	0.01	--	--	--	--
Cladocerans:						
Alona	--	0.01	--	--	--	--
Bosmina	16.13	9.09	19.09	11.81	8.38	4.12
Ceriodaphnia	--	--	--	--	0.02	--
Daphnia	0.66	1.20	0.71	0.67	0.50	0.71
Diaphanosoma	0.07	--	--	0.03	0.05	--
Eurycercus	--	--	--	--	--	--
Holopedium	0.17	0.20	0.28	0.13	0.11	0.06
Leptodera	0.02	0.02	--	--	--	--
Polyphemus	--	0.01	--	--	--	--
Rotifers:						
Asplanchna	0.19	0.03	0.06	0.03	0.05	0.04
TOTAL	24.63	19.51	27.59	22.00	18.74	15.77
Diversity index	1.51	1.96	1.38	1.67	1.81	1.77

Table 4 continued

Organisms	Stations NDC-4-1	NDC-4-2	NDC-4-3	NDC-4-4	NDC-7-1	NDC-7-2
Copepods:						
Diaptomids	1.21	1.55	5.78	9.63	5.24	3.54
Epischura	0.04	--	0.05	0.07	0.03	0.05
Eurytemora	0.04	--	0.01	0.01	--	0.04
Limnocalanus	--	--	--	0.01	--	--
Senecella	--	0.02	--	--	--	--
Cyclopoids	4.29	3.32	2.41	1.99	6.89	4.03
Harpactacoids	--	--	--	--	--	--
Cladocerans:						
Alona	--	--	--	--	--	--
Bosmina	21.62	10.75	2.15	2.25	12.13	11.04
Ceriodaphnia	0.04	0.02	--	--	--	--
Daphnia	0.33	0.64	0.39	0.69	0.75	0.48
Diaphanosoma	0.25	--	--	0.02	--	--
Eurycercus	--	--	--	--	--	--
Holopedium	0.29	0.11	--	0.08	0.38	0.17
Leptodera	--	0.04	--	--	0.03	0.04
Polyphemus	0.04	0.04	--	--	0.03	0.05
Rotifers:						
Asplanchna	0.08	0.04	0.01	0.04	0.07	0.01
TOTAL	28.23	16.53	10.80	14.79	25.55	19.45
Diversity Index	1.18	1.51	1.66	1.54	1.79	1.66

Table 4 continued

Organisms	Stations					
	NDC-7-3	NDC-7-4	NDC-7-5	SDC-.25-1	SDC-.5-1	SDC-.25-2
Copepods:						
Diaptomids	4.92	5.71	9.75	4.82	3.10	*
Epischura	0.07	0.04	0.08	0.05	--	*
Eurytemora	--	0.03	0.03	*	--	*
Limnocalanus	--	--	--	*	--	*
Senecella	--	--	--	*	--	*
Cyclopoids	3.60	2.61	2.40	3.93	5.30	*
Harpactacoids	--	--	0.01	--	--	*
Cladocerans:						
Alona	--	--	--	--	--	*
Bosmina	9.90	1.88	3.18	11.00	25.90	*
Ceriodaphnia	--	--	--	--	--	*
Daphnia	0.46	0.20	0.73	0.61	0.88	*
Diaphanosoma	--	0.02	--	0.02	0.03	*
Eurycercus	--	--	--	--	--	*
Holopedium	0.13	0.06	0.11	0.14	0.13	*
Leptodera	0.02	--	--	--	0.03	*
Polyphemus	--	--	--	--	--	*
Rotifers:						
Asplanchna	--	--	0.06	0.05	0.24	*
TOTAL	19.10	10.55	16.35	20.62	35.61	
Diversity index	1.67	1.64	1.65	1.68	1.28	

*Sample broken

Table 4 continued

Organisms	Stations					
	SDC-.5-3	SDC-1-1	SDC-1-2	SDC-1-3	SDC-2-1	SDC-2-2
Copepods:						
Diaptomids	*	3.58	2.89	7.09	1.88	4.10
Epischura	*	--	0.02	0.10	0.08	0.04
Eurytemora	*	--	--	--	--	0.01
Limnocalanus	*	--	--	0.03	--	--
Senecella	*	--	--	--	--	--
Cyclopoids	*	13.80	4.55	5.44	2.48	2.96
Harpactacoids	*	--	--	--	--	--
Cladocerans:						
Alona	*	--	--	--	--	--
Bosmina	*	14.50	18.73	23.28	13.48	9.21
Ceriodaphnia	*	--	--	--	--	--
Daphnia	*	0.91	1.07	1.21	0.96	0.70
Diaphanosoma	*	--	0.02	0.03	--	0.03
Eurycercus	*	--	--	--	--	--
Holopedium	*	0.37	0.47	0.28	0.60	0.26
Leptodera	*	0.05	0.02	0.03	--	0.03
Polyphemus	*	--	0.02	--	0.04	--
Rotifers:						
Asplanchna	*	0.05	0.12	0.01	--	--
TOTAL		33.26	27.91	37.50	19.52	17.34
Diversity index		1.64	1.49	1.55	1.49	1.75

*Sample broken

Table 4 continued

Organisms	Stations SDC-2-3	SDC-2-4	SDC-4-1	SDC-4-2	SDC-4-3	SDC-4-4
Copepods:						
Diaptomids	26.29	19.21	3.42	9.33	11.26	8.58
Epischura	0.26	0.31	0.03	0.10	--	0.05
Eurytemora	0.11	0.03	--	0.05	--	--
Limnocalanus	--	--	--	--	--	0.02
Senecella	--	--	--	--	0.15	0.02
Cyclopoids	16.99	14.89	2.13	8.07	8.07	4.58
Harpactacoids	--	--	--	--	--	--
Cladocerans:						
Alona	--	--	--	--	--	--
Bosmina	59.29	17.54	5.41	10.67	14.73	4.10
Ceriodaphnia	--	--	--	--	--	--
Daphnia	1.95	2.89	0.56	1.58	1.14	0.83
Diaphanosoma	0.11	--	--	0.10	--	0.05
Eurycercus	--	--	--	--	--	--
Holopedium	0.79	0.31	0.07	0.37	0.31	0.11
Leptodera	0.15	--	--	--	--	--
Polyphemus	--	--	--	--	--	0.02
Rotifers:						
Asplanchna	0.15	0.14	0.17	0.05	0.09	0.12
TOTAL	106.09	55.32	11.79	30.32	35.75	18.48
Diversity index	1.62	1.90	0.88	1.95	1.81	1.87

Table 4 continued

Organisms	Stations				
	SDC-7-1	SDC-7-2	SDC-7-3	SDC-7-4	SDC-7-5
Copepods:					
Diaptomids	8.05	2.50	4.63	13.89	8.17
Epischura	0.17	0.01	0.08	0.24	0.05
Eurytemora	--	0.02	0.03	0.05	--
Limnocalanus	--	--	--	--	--
Senecella	--	--	--	--	--
Cyclopoids	7.31	1.81	2.52	5.97	7.95
Harpactacoids	--	--	--	--	--
Cladocerans:					
Alona	--	--	--	--	--
Bosmina	13.47	5.55	4.67	10.02	3.05
Ceriodaphnia	--	--	--	--	--
Daphnia	0.96	0.20	0.64	0.91	0.72
Diaphanosoma	--	0.02	0.03	--	--
Eurycercus	--	--	--	--	--
Holopedium	0.20	0.11	0.07	0.19	0.09
Leptodera	0.03	--	--	--	0.04
Polyphemus	--	--	--	--	--
Rotifers:					
Asplanchna	0.03	0.03	0.03	--	--
TOTAL	30.22	10.25	12.70	31.27	20.07
Diversity index	1.79	1.67	1.89	1.76	1.72

than 5 individuals per liter. Diaptomids in general were most abundant offshore (Figure 4); all stations offshore of the heavy line in Figure 4 had 7 or more individuals per liter, whereas all stations shoreward of the line had 1-6 per liter. Highest diaptomid abundances (11-26 per liter) occurred at four of the stations south of the plant site (enclosed by the broken line in Figure 4) which had the highest total zooplankton abundances. Cyclopoids occurred throughout the study area in concentrations between 2 and 5 individuals per liter (Figure 5), except for a few scattered nearshore stations and six stations south of the plant site (circled in Figure 5), where 6-17 per liter were found. These distributions suggest a large patch of plankton-rich (offshore?) water occurred south of the plant site on 12 November 1970.

A.7 Study of Benthic Organisms

Benthos Techniques

Benthic organisms were collected by use of the Ponar grab-sampler. Two grabs were combined and passed together through a washing device in which the benthic organisms were retained on a 0.5-mm mesh screen. In subsequent counting, the counts were divided by two to give the average of the duplicate samples. Organisms from the washing device then were collected into pint Mason jars, labeled internally and externally, preserved with buffered formalin, and returned to the laboratory for processing. In the laboratory, the samples were concentrated on a small mesh net, and transferred with minimum fluid to the counting tray.

For general survey purposes, the benthos are counted into the groups: amphipods, oligochaetes, sphaeriids, chironomids, and others (mostly leeches and snails). The averaged counts were converted by standard factors to give numbers of organisms per square meter. The counted samples are preserved by appropriate standard museum techniques and retained as a reference collection. Initially, another compromise was needed to expedite enumeration of the oligochaetes. These worms tend to fragment during processing, and it was not possible at first for us to rapidly distinguish fragments from whole individuals. Therefore, to estimate oligochaete abundance, all worms and parts of worms were counted, and the total divided by three. More detailed examination of samples has shown that this factor varies from sample to sample with the result that oligochaete abundances obtained by this method are fairly good estimates rather than real counts. Oligochaetes are now counted by head ends, and ignoring other fragments (literally counting heads).

Inconsistencies between abundances given in Table 5 and in Table 39 of Part XIII are due largely to head counts being used in this report while fragments/3 was used in Part XIII Tables 38 through 43. All other tables in Part XIII are based on the head count method. Table 5 gives, by depth, the percent of population comprised by major taxa and also the total numbers of organisms per square meter as well as the numbers of taxa identified and the diversity indices computed from species counts for each of the 35 stations sampled.

This report details the species compositions (Table 6) and other aspects of 35 benthos samples from stations in all parts of the survey area, all based on the oligochaete head count method.

Benthos Abundances

Many aspects of the November 1970 benthos data were reported in Part XIII of this report series and are here repeated for the reader's convenience: average abundances and frequencies of occurrence of species for all stations combined (Part XIII, Table 47) is here Table 7; percentage composition by depth zones (XIII, Table 49) is here Table 8; and average abundances of dominant taxa by benthic (depth) zones (XIII, Table 51) is here Table 9. Other tables and figures here included are specific unto this report.

In comparison to July 1970, the November 1970 collections showed greater abundances of Tubificidae and *Pisidium*, while *Pontoporeia affinis* was less abundant (Table 7). The pattern of depth distribution and benthic zonation was, however, little affected by the shifts in dominant taxa abundances that took place between July and November (Tables 8 and 9).

Table 5. Benthos summary table, Cook Plant biological survey of 12 November 1970.

	Depth, m	Amphipods %	Chironomids %	Oligochaetes %	Sphaeriids %	Others %	Total number per m^2	Number of Taxa	Species diversity index
SDC-2-1	4.5	0.0	0.0	35.4	64.6	0.0	127	2	0.94
NDC-.5-1	5.1	20.0	20.0	0.0	60.0	0.0	45	3	1.37
NDC-7-1	5.8	0.0	0.0	100.0	0.0	0.0	54	2	0.65
SDC-.5-1	5.8	3.2	33.0	43.7	19.1	1.1	852	6	2.05
NDC-2-1	6.1	3.2	23.7	31.2	41.9	0.0	844	8	2.19
SDC-7-1	6.2	37.5	62.5	0.0	0.0	0.0	72	4	1.91
NDC-7-2	8.2	12.8	22.3	58.7	4.6	0.9	980	10	2.54
NDC-.5-2	9.1	2.4	0.0	65.3	30.6	1.7	2,615	6	1.94
SDC-7-2	9.1	3.6	15.7	63.9	16.9	0.0	753	8	2.55
NDC-2-2	9.2	5.3	17.2	56.9	17.2	0.9	1,897	12	2.76
SDC-2-2	9.3	4.3	11.3	49.3	29.2	5.9	1,661	13	2.82
SDC-.5-2	9.9	3.7	11.1	38.9	46.3	0.0	1,962	8	2.17
SDC-.25-1	13.4	10.4	12.0	33.6	41.6	2.4	1,116	11	2.49
NDC-.25-1	13.7	8.5	8.8	36.6	42.2	3.9	5,531	21	3.04
DC-2	13.9	0.6	23.1	46.3	29.0	0.9	2,908	21	3.34
NDC-7-3	14.2	49.6	4.1	42.2	4.1	0.0	1,098	7	1.63
NDC-2-3	15.1	4.7	27.8	61.7	4.8	1.0	7,163	22	3.27
SDC-7-3	15.4	0.2	4.6	83.9	11.2	0.1	56,414	24	2.91
SDC-.5-3	15.8	25.2	14.0	39.6	20.8	0.3	2,908	14	2.92
SDC-2-3	16.3	3.9	14.8	63.6	17.3	0.3	10,415	19	2.61
NDC-7-4	16.5	20.6	13.6	52.0	13.4	0.3	8,007	15	2.82
SDC-7-4	16.8	43.7	11.7	36.5	7.6	0.5	1,788	12	2.47
DC-3	16.9	11.7	43.6	37.8	4.6	2.3	1,552	17	2.89
NDC-.5-3	18.3	23.3	7.4	19.5	47.7	2.1	4,759	15	2.79
SDC-1-3	19.5	20.8	7.2	23.4	43.9	4.8	10,413	15	2.84

Table 5 continued.

	Depth, m	Amphipods %	Chironomids %	Oligochaetes %	Sphaeriids %	Others %	Total number per m^2	Number of Taxa	Species diversity index
DC-4	20.1	56.9	3.5	15.0	23.6	1.1	8,126	14	2.13
NDC-1-3	20.4	76.1	3.5	12.8	7.7	0.0	3,677	11	1.42
SDC-7-5	21.5	4.1	6.0	61.0	27.1	1.7	10,412	15	3.18
SDC-2-4	22.7	79.1	8.7	8.7	1.7	1.7	517	7	1.20
NDC-7-5	23.2	46.1	3.5	20.5	28.9	1.0	6,249	16	2.42
DC-5	24.1	83.6	0.9	12.5	3.0	0.0	6,299	10	0.91
NDC-2-4	24.2	56.6	0.3	32.4	10.0	0.7	10,223	10	1.67
SDC-4-4	32.5	42.3	0.3	36.5	20.1	0.8	5,547	10	2.02
DC-6	39.0	41.1	0.0	27.1	31.2	0.6	9,215	8	2.10
NDC-4-4	42.4	46.5	0.4	28.7	24.2	0.3	20,420	11	2.19

Table 6. Station collections of benthos during the 12 November 1970 survey.

	SDC-2-1	NDC-.5-1	NDC-7-1	SDC-.5-1	NDC-2-1	SDC-7-1	NDC-7-2
Chironomidae							
Chironomus anthracinus-group							
Chironomus fluviatilis-group				136	73	18	27
Kiefferulus sp.							
Cryptochironomus sp. 2				136	64	18	191
Cryptochironomus sp. 3		9		9	18	9	
Paracladopelma nereis					27		
Polypedilum cf. *scalaenum*							
Tanytarsini spp.							
Procladius spp.							9
Potthastia cf. *longimanus*					18		
Monodiamesa cf. *bathyphila*[1]							
Heterotrissocladius cf. *subpilosus*							
Heterotrissocladius cf. *grimshawi*							
Gastropoda							
Lymnaea spp.							
Valvata sp.							
Hirudinea							
Helobdella stagnalis				9			

[1]According to Saether's (1973) recent revision, most if not all our specimens should be assigned to the species *M. tuberculata*

Table 6 continued.

	SDC-2-1	NDC-.5-1	NDC-7-1	SDC-.5-1	NDC-2-1	SDC-7-1	NDC-7-2
Helobdella elongata							
Glossiphonia complanata							
Nephelopsis obscura							
Amphipoda							
Pontoporeia affinis		9		27	27	27	127
Oligochaeta							
Stylodrilus heringianus							
Limnodrilus hoffmeisteri		9		36	36		100
Limnodrilus cervix							
Limnodrilus angustipenis							18
Limnodrilus profundicola							
Potamothrix moldaviensis							45
Potamothrix vejdovskyi							
Peloscolex freyi							
Peloscolex multisetosus							
Tubifex tubifex							
Aulodrilus americanus			9				
Aulodrilus pluriseta							
Immatures with hair setae							
Immatures w/o hair setae	45	18	45	336	227		418

Table 6 continued.

	SDC-2-1	NDC-.5-1	NDC-7-1	SDC-.5-1	NDC-2-1	SDC-7-1	NDC-7-2
Sphaeriidae							
Sphaerium striatinum							18
Sphaerium nitidum							
Sphaerium transversum							9
Sphaerium sp. 2							
Sphaerium sp. 3							
Pisidium ssp.	82			163	354		18

	NDC-.5-2	SDC-7-2	NDC-2-2	SDC-2-2	SDC-.5-2	SDC-.25-1
Chironomidae						
Chironomus anthracinus-group						
Chironomus fluviatilis-group		27	18	36	45	73
Kiefferulus sp.						
Cryptochironomus sp. 2		91	300	145	173	54
Cryptochironomus sp. 3				9		
Paracladopelma nereis						
Polypedilum cf. *scalaenum*						
Tanytarsini spp.						
Procladius spp.						

Table 6 continued.

	NDC-.5-2	SDC-7-2	NDC-2-2	SDC-2-2	SDC-.5-2	SDC-.25-1
Potthastia cf. *longimanus*						
Monodiamesa cf. *bathyphila*[1]			9			9
Heterotrissocladius cf. *subpilosus*						
Heterotrissocladius cf. *grimshawi*						
Gastropoda						
Lymnaea spp.			9	27		
Valvata sp.				27		9
Hirudinea						
Helobdella stagnalis	45		9	9		
Helobdella elongata				18		
Glossiphonia complanata						
Nephelopsis obscura						
Amphipoda						
Pontoporeia affinis	64	27	100	73	73	118
Oligochaeta						
Stylodrilus heringianus			27			18
Limnodrilus hoffmeisteri	81	82	130	64	145	118
Limnodrilus cervix		18				
Limnodrilus angustipenis			213	118		
Limnodrilus profundicola						
Potamothrix moldaviensis	122	27	95	109	66	27

Table 6 continued.

	NDC-.5-2	SDC-7-2	NDC-2-2	SDC-2-2	SDC-.5-2	SDC-.25-1
Potamothrix vejdovskyi						
Peloscolex freyi		9			13	
Peloscolex multisetosus						
Tubifex tubifex						
Aulodrilus americanus						
Aulodrilus pluriseta						
Immatures with hair setae						
Immatures w/o hair setae	1,504	345	615	536	539	218
Sphaeriidae						
Sphaerium striatinum	82		36	18	18	27
Sphaerium nitidum						9
Sphaerium transversum						
Sphaerium sp. 2						
Sphaerium sp. 3						
Pisidium spp.	717	127	336	472	890	436

Table 6 continued.

	NDC-.25-1	DC-2	NDC-7-3	NDC-2-3	SDC-7-3	SDC-.5-3
Chironomidae						
Chironomus anthracinus-group		291	18	835	672	
Chironomus fluviatilis-group	64	82		409	64	154
Kiefferulus sp.		18		18	54	
Cryptochironomus sp. 2	173	64	9	27	145	73
Cryptochironomus sp. 3					18	
Paracladopelma nereis						
Polypedilum cf. *scalaenum*	9					
Tanytarsini spp.		9				
Procladius spp.	191	200	18	645	1,625	100
Potthastia cf. *longimanus*	27			9	18	18
Monodiamesa cf. *bathyphila*[1]	27	9		45	18	64
Heterotrissocladius cf. *subpilosus*						
Heterotrissocladius cf. *grimshawi*						
Gastropoda						
Lymnaea spp.	45					
Valvata sp.	45	18			27	
Hirudinea						
Helobdella stagnalis	100	9		64	18	
Helobdella elongata						
Glossiphonia complanata				9		
Nephelopsis obscura					9	

Table 6 continued.

	NDC-.25-1	DC-2	NDC-7-3	NDC-2-3	SDC-7-3	SDC-.5-3
Nephelopsis obscura					9	
Amphipoda						
Pontoporeia affinis	472	18	545	336	100	735
Oligochaeta						
Stylodrilus heringianus	159		36	100	305	234
Limnodrilus hoffmeisteri	480	448		1,509	5,958	312
Limnodrilus cervix	80	100		617	5,509	17
Limnodrilus angustipenis		50	9		609	
Limnodrilus profundicola						
Potamothrix moldaviensis	116	100		137	911	
Potamothrix vejdovskyi	80	25		412	1,080	
Peloscolex freyi		25			609	31
Peloscolex multisetosus						
Tubifex tubifex						
Aulodrilus americanus	80	100				
Aulodrilus pluriseta					2,308	
Immatures with hair setae	80	25		823	10,689	17
Immatures w/o hair setae	960	473	418	823	19,340	545
Sphaeriidae						
Sphaerium striatinum	118	45		9	18	27
Sphaerium nitidum	91	118		127	27	91

Table 6 continued.

	NDC-.25-1	DC-2	NDC-7-3	NDC-2-3	SDC-7-3	SDC-.5-3
Sphaerium transversum	9			9		
Sphaerium sp. 2						
Sphaerium sp. 3				9		
Pisidium spp.	2,125	681	45	191	6,283	490

	SDC-2-3	NDC-7-4	SDC-7-4	DC-3	NDC-.5-3	SDC-1-3
Chironomidae						
Chironomus anthracinus-group		100				45
Chironomus fluviatilis-group	109	18	36	236	82	9
Kiefferulus sp.						
Cryptochironomus sp. 2	18		18	9	18	
Cryptochironomus sp. 3						
Paracladopelma nereis						
Polypedilum cf. *scalaenum*						
Tanytarsini spp.						
Procladius spp.	1,344	899	64	418	163	699
Potthastia cf. *longimanus*	9	27	18	9	82	
Monodiamesa cf. *bathyphila*[1]	64	45	73	9	9	

Table 6 continued.

	SDC-2-3	NDC-7-4	SDC-7-4	DC-3	NDC-.5-3	SDC-1-3
Heterotrissocladius cf. *subpilosus*						
Heterotrissocladius cf. *grimshawi*						
Gastropoda						
Limnaea spp.		18	9	9	36	27
Valvata sp.	18			9	64	445
Hirudinea						
Helobdella stagnalis	9	9		9		27
Helobdella elongata						
Glossiphonia complanata						
Nephelopsis obscura	9					
Amphipoda						
Pontoporeia affinis	409	1,653	781	182	1,108	2,161
Oligochaeta						
Stylodrilus heringianus	54		54	27	222	1,192
Limnodrilus hoffmeisteri		641	27	236	56	248
Limnodrilus cervix						
Limnodrilus angustipenis						
Limnodrilus profundicola						
Potamothrix moldaviensis		320	54	18	130	99
Potamothrix vejdovskyi	221	320		18		
Peloscolex freyi	74				37	149
Peloscolex multisetosus						

Table 6 continued.

	SDC-2-3	NDC-7-4	SDC-7-4	DC-3	NDC-.5-3	SDC-1-3
Tubifex tubifex		80?[2]		9?[2]		
Aulodrilus americanus	221					
Aulodrilus pluriseta	148					
Immatures with hair setae	2,287	401		109		50
Immatures w/o hair setae	3,614	2,404	518	173	482	695
Sphaeriidae						
Sphaerium striatinum	9	73		9	27	118
Sphaerium nitidum	73	18	9	27	527	881
Sphaerium transversum	18					
Sphaerium sp. 2						
Sphaerium sp. 3						
Pisidium spp.	1,707	981	127	36	1,716	3,568

	DC-4	NDC-1-3	SDC-7-5	SDC-2-4	NDC-7-5	DC-5	NDC-2-4
Chironomidae							
Chironomus anthracinus-group			45			9	
Chironomus fluviatilis-group	36						
Kiefferulus sp.							

[2]Identifications of not fully mature specimens with weakly developed penis sheaths.

Table 6 continued.

	DC-4	NDC-1-3	SDC-7-5	SDC-2-4	NDC-7-5	DC-5	NDC-2-4
Cryptochironomus sp. 2							
Cryptochironomus sp. 3							
Paracladopelma nereis							
Polypedilum cf. *scalaenum*							
Tanytarsini spp.					18		
Procladius spp.	109	45	581	45	200	9	9
Potthastia cf. *longimanus*	9						
Monodiamesa cf. *bathyphila*[1]	127	82				27	9
Heterotrissocladius cf. *subpilosus*							9
Heterotrissocladius cf. *grimshawi*						9	
Gastropoda							
Lymnaea spp.					9		36
Valvata sp.	27		36		9		
Hirudinea							
Helobdella stagnalis	64		145	9	36		27
Helobdella elongata							
Glossiphonia complanata							
Nephelopsis obscura					9		
Amphipoda							
Pontoporeia affinis	4,622	2,797	427	409	2,878	5,266	5,793

Table 6 continued.

	DC-4	NDC-1-3	SDC-7-5	SDC-2-4	NDC-7-5	DC-5	NDC-2-4
Oligochaeta							
Stylodrilus heringianus	378	300	1,082	27	628	709	2,751
Limnodrilus hoffmeisteri	21		432		144	32	191
Limnodrilus cervix		9					
Limnodrilus angustipenis							
Limnodrilus profundicola							
Potamothrix moldaviensis	189	36	432		48	16	
Potamothrix vejdovskyi			361	9	48		
Peloscolex freyi	42	9	72				
Peloscolex multisetosus			9		9		
Tubifex tubifex							
Aulodrilus americanus							
Aulodrilus pluriseta							
Immatures with hair setae		18	432				
Immatures w/o hair setae	587	100	3,534	9	407	32	372
Sphaeriidae							
Sphaerium striatinum	18	18	64		27		
Sphaerium nitidum	544	27	1,389		717	27	18
Sphaerium transversum							
Sphaerium sp. 2					9		
Sphaerium sp. 3							
Pisidium spp.	1,353	236	1,371	9	1,053	163	908

Table 6 continued.

	SDC-4-4	DC-6	NDC-4-4
Chironomidae			
Chironomus anthracinus-group	9		
Chironomus fluviatilis-group			
Kiefferulus sp.			
Cryptochironomus sp. 2			
Cryptochironomus sp. 3			
Paracladopelma nereis			
Polypedilum cf. *scalaenum*			
Tanytarsini spp.			
Procladius spp.	9		9
Potthastia cf. *longimanus*			
Monodiamesa cf. *bathyphila*[1]			
Heterotrissocladius cf. *subpilosus*			64
Heterotrissocladius cf. *grimshawi*			
Gastropoda			
Lymnaea spp.			
Valvata sp.	18	9	
Hirudinea			
Helobdella stagnalis	9	9	9
Helobdella elongata			
Glossiphonia complanata			
Nephelopsis obscura			

Table 6 continued.

	SDC-4-4	DC-6	NDC-4-4
Amphipoda			
Pontoporeia affinis	2,352	3,805	9,507
Oligochaeta			
Stylodrilus heringianus	1,525	1,044	2,291
Limnodrilus hoffmeisteri		125	117
Limnodrilus cervix			
Limnodrilus angustipenis			
Limnodrilus profundicola			59
Potamothrix moldaviensis	218	167	59
Potamothrix vejdovskyi			
Peloscolex freyi			
Peloscolex multisetosus			
Tubifex tubifex			
Aulodrilus americanus			
Aulodrilus pluriseta			
Immatures with hair setae	36	459	1,292
Immatures w/o hair setae	254	710	2,056
Sphaeriidae			
Sphaerium striatinum	109		
Sphaerium nitidum			36
Sphaerium transversum			
Sphaerium sp. 2			
Sphaerium sp. 3			
Pisidium spp.	1,008	2,887	4,921

Table 7. Species of benthos in selected samples from the major surveys. $\bar{x}/m^2$ = mean density over all samples for each month; freq. = frequency, or fraction of the samples in which a species occurred each month; n = the number of samples analysed in each month. Two ponars were combined as a single sample for July and November, 1970; one ponar was used for April and July, 1971.

Species	Jul 1970 n = 25		Nov 1970 n = 35		Apr 1971 n = 42		Jul 1971 n = 38	
	$\bar{x}/m^2$	freq.	$\bar{x}/m^2$	freq.	$\bar{x}/m^2$	freq.	$\bar{x}/m^2$	freq.
Amphipoda								
Pontoporeia affinis	1762.0	0.84	1344.0	0.94	1232.0	0.70	2560.0	0.87
Oligochaeta Lumbriculudae								
Stylodrilus heringianus	522.0	0.60	376.0	0.63	806.0	0.60	784.0	0.42
Oligochaeta Tubificidae								
Limnodrilus hoffmeisteri[1]	267.0	0.80	337.0	0.77	163.0	0.68	1060.0	0.87
L. angustipenis[1]	12.0	0.28	29.0	0.17	19.0	0.28	94.0	0.37
L. cervix[1]	8.0	0.20	181.0	0.20	4.0	0.08	12.0	0.13
L. profundicola[1]	3.0	0.20	2.0	0.03	3.0	0.15	37.0	0.34
L. claparedeanus[1]	-	-	-	-	0.5	0.03	5.0	0.08
Potamothrix moldaviensis[1]	27.0	0.36	101.0	0.69	28.0	0.45	185.0	0.71
P. vejdovskyi	0.7	0.04	74.0	0.29	5.0	0.08	63.0	0.34
Peloscolex freyi[1]	31.0	0.48	31.0	0.31	3.0	0.10	134.0	0.45
P. variegatus	0.4	0.04	-	-	-	-	-	-
P. multisetosus	-	-	0.5	0.06	-	-	-	-
Tubifex tubifex[2]	-	-	3.0	0.06	19.0	0.18	44.0	0.21

[1] Species of Tubificidae whose immatures are combined in the category "immatures w/o hair setae."

[2] Species whose immatures are combined in the category "immatures w/hair setae." *Ilyodrilus templetoni* may also contribute to this group.

Table 7 continued.

	Jul 1970 n = 25		Nov 1970 n = 35		Apr 1971 n = 42		Jul 1971 n = 38	
	$\bar{x}/m^2$	freq.	$\bar{x}/m^2$	freq.	$\bar{x}/m^2$	freq.	$\bar{x}/m^2$	freq.
Aulodrilus americanus	3.0	0.08	12.0	0.11	-	-	2.0	0.03
A. pluriseta	-	-	70.0	0.06	-	-	2.0	0.03
immatures w/o hair setae	218.0	0.80	1239.0	0.97	587.0	0.88	595.0	0.89
immatures w/hair setae	6.0	0.08	478.0	0.40	48.0	0.25	69.0	0.21
Hirudinea								
Helobdella stagnalis	22.0	0.40	18.0	0.54	9.0	0.10	10.0	0.26
Glossiphonia complanata	0.4	0.04	0.3	0.03	-	-	-	-
Nephelopsis obscura	-	-	0.8	0.9	-	-	0.5	0.03
other Hirudinea	-	-	0.5	0.03	-	-	0.5	0.03
Pelecypoda Sphaeriidae								
Sphaerium striatinum	26.0	0.56	25.0	0.60	16.0	0.33	18.0	0.29
S. nitidum	147.0	0.48	139.0	0.54	106.0	0.30	137.0	0.42
S. transversum	2.0	0.12	1.0	0.11	-	-	-	-
S. securis	-	-	-	-	-	-	1.0	0.05
Pisidium spp.	302.0	0.80	1013.0	0.91	446.0	0.78	615.0	0.82
Gastropoda								
Lymnaea spp.	0.7	0.08	6.0	0.26	3.0	0.10	23.0	0.39
Valvata sp.	1.4	0.12	22.0	0.40	12.0	0.28	2.0	0.11
Bulimus sp.	-	-	-	-	-	-	0.5	0.03
Insecta Diptera Chironomidae								
Chironomus fluviatilis-gr.	18.0	0.60	50.0	0.60	15.0	0.28	110.0	0.42

Table 7 continued.

Species	Jul 1970 n = 25		Nov 1970 n = 35		Apr 1971 n = 42		Jul 1971 n = 38	
	$\bar{x}/m^2$	freq.	$\bar{x}/m^2$	freq.	$\bar{x}/m^2$	freq.	$\bar{x}/m^2$	freq.
C. anthracinus-gr.	14.0	0.32	58.0	0.26	10.0	0.15	68.0	0.39
Kiefferulus sp.	2.0	0.20	3.0	0.09	-	-	-	-
Cryptochironomus sp. 1	0.4	0.04	-	-	-	-	-	-
C. sp. 2	38.0	0.64	49.0	0.54	31.0	0.40	30.0	0.45
C. sp. 3	-	-	2.0	0.17	0.5	0.03	1.0	0.08
Paracladopelma cf. *obscura*	6.0	0.32	-	-	9.0	0.20	21.0	0.53
P. nereis	32.0	0.32	0.8	0.03	-	-	36.0	0.32
Parachironomus cf. *demeijerei*	6.0	0.28	-	-	-	-	31.0	0.24
Harnischia sp.	-	-	-	-	-	-	0.5	0.03
Polypedilum cf. *scalaenum*	7.0	0.28	0.8	0.03	-	-	36.0	0.32
P. fallax-gr.	0.4	0.04	-	-	-	-	-	-
Tanytarsini spp.	0.4	0.04	0.8	0.06	-	-	10.0	0.24
Heterotrissocladius cf. *subpilosus*	0.7	0.04	2.0	0.06	13.0	0.05	2.0	0.03
H. cf. *grimshawi*	-	-	0.3	0.03	4.0	0.08	3.0	0.04
Psectrocladius cf. *simulans*	-	-	-	-	-	-	1.0	0.03
Monodiamesa cf. *bathyphila*[3]	1.4	0.16	18.0	0.46	9.0	0.25	5.0	0.11
Potthastia cf. *longimanus*	-	-	7.0	0.31	7.0	0.25	-	-
Procladius sp.	40.0	0.44	211.0	0.63	33.0	0.45	2.0	0.11
Number of species	34		36		27		40	

[3]According to Saether's (1973) recent revision, most if not all our specimens should be assigned to the species

Table 8. Contribution of dominant taxa to the benthos community.

	% of Total Fauna			
	Jul 1970	Nov 1970	Apr 1971	Jul 1971
Pontoporeia affinis	49.9	22.8	33.8	37.6
Stylodrilus heringianus	14.8	6.7	22.1	11.5
Tubificidae	16.3	43.3	24.2	33.8
Sphaerium nitidum	4.2	2.4	2.9	2.0
Pisidium spp.	8.6	17.2	12.2	9.0
Chironomidae	4.7	6.8	3.6	5.2
Remainder	1.5	0.8	1.2	0.9
Total #/m^2	3528	5906	3641	6810

Table 9. Mean numbers by depth zone, for species dominant at some time of year, on 12 November 1970.

Species	0-8m	8-16m	16-24m	>24m
Pontoporeia affinis	15	214	1,584	5,345
Stylodrilus heringianus	0	68	360	1,664
Limnodrilus hoffmeisteri (mature)	14	725	164	93
Limnodrilus angustipenis (mature)	0	78	0	0
Peloscolex freyi (mature)	0	53	35	0
Sphaerium nitidum	0	36	384	36
Pisidium spp.	100	985	1,105	1,977
Chironomus anthracinus-gr.	0	140	17	4
Cryptochironomus sp. 2	36	111	3	0
Paracladopelma nereis	5	0	0	0
Parachironomus cf. *demeijerei*	0	0	0	0
Polypedilum cf. *scalaenum*	0	1	0	0

Figure 6 shows the total numbers of benthic macroinvertebrates, plotted against depth, for the 35 selected samples. Stations near shore are coded for their distance from shore. It is clear that stations near shore had very few animals. Proceeding away from shore, the average number of individuals increased, but the variability among stations at similar depths increased also. The few stations over 30 meters deep seemed to have somewhat more uniformly high abundances. There was no consistent tendency for stations in the center of the survey area to have more benthos than stations farther north or south. This was different from July, when stations in front of the plant had more benthos than stations farther north and south.

<u>Benthic Zone 0 (0 to 8 m)</u>

All of these stations were 1/4 mile (400 m) from shore, and together averaged 332 organisms per m^2. Tubificidae *(Limnodrilus hoffmeisteri)* with 38% of the population, *Pisidium* with 30%, and Chironomidae with 27% were the major component forms. *Chironomus* fluviatilis-group and *Cryptochironomus* spp. made up most of the Chironomidae. Two species which were abundant or frequent in the 10 July 1970 collections from this zone, *Paracladopelma nereis* and *Parachironomus* cf. *demeijerei* (Mozley and Garcia 1972), were nearly absent in November. These midges had emerged from the lake in summer and the next generation had not yet grown to a size which could be retained by our 0.5-mm sieve in November.

<u>Benthic Zone 1 (8 to 16 m)</u>

This benthic zone, including mostly stations at 1/2 to 3/4 mile (800 and 1200 m) from shore, had many more animals. The average total abundance was 2,556 organisms per m^2. One sample, SDC-7-3, was anomalous (see below) and

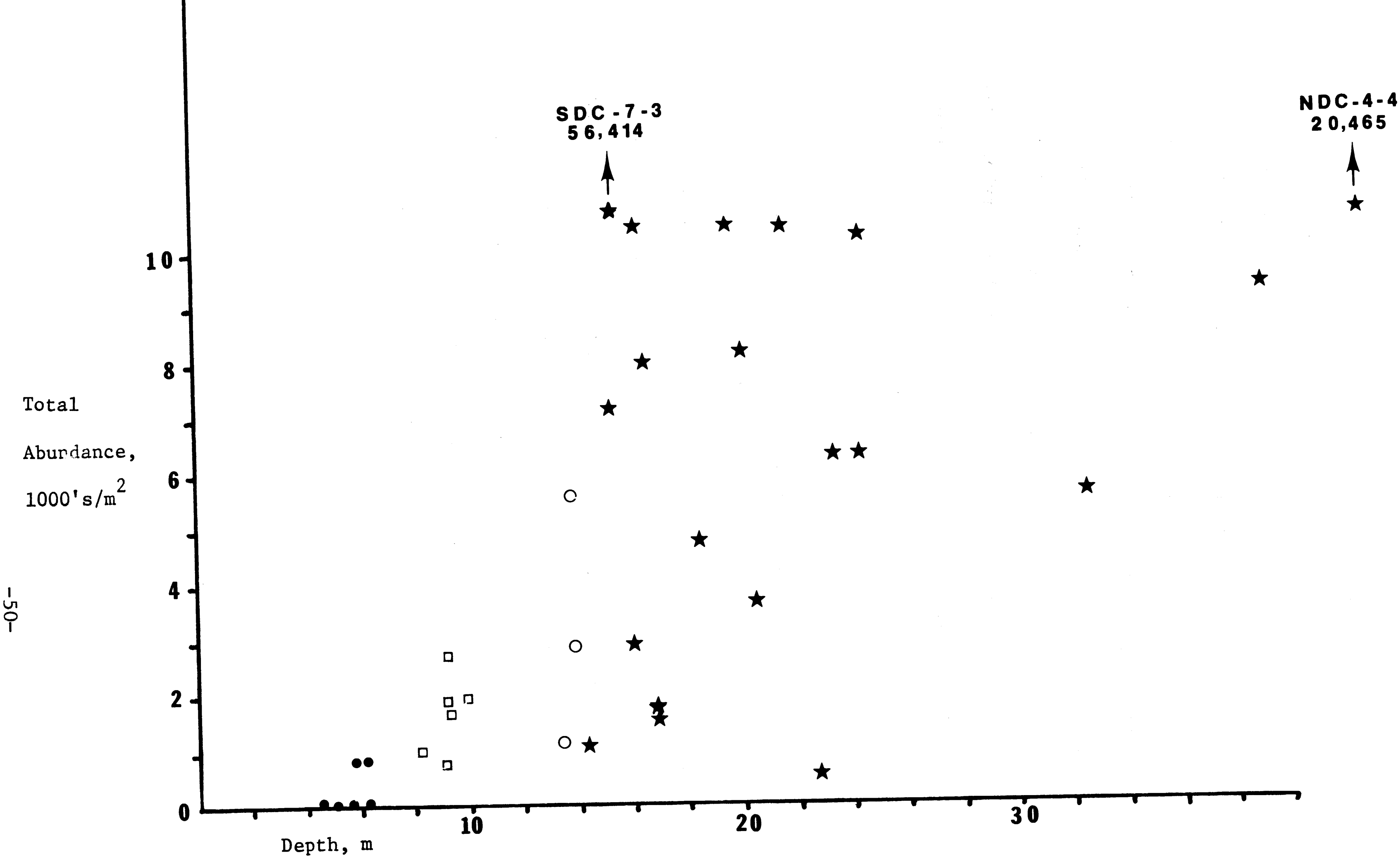

Figure 6. Total abundance of benthic macroinvertebrates at 35 selected stations of the 12 November 1970 biological survey. Solid circles - stations 1/4 mile (400 m) off shore. Squares - stations 1/2 mile (800 m) off shore. Open circles - stations 3/4 mile (1200 m) off shore. Stars - stations more than 3/4 mile off shore.

was excluded from this average and from following percentages. The major taxa in this zone were still more heavily dominated by oligochaetes (48%), and several additional species were present in abundance: *Potamothrix moldaviensis*, other *Limnodrilus* species, *Aulodrilus americanus*, *Potamothrix vejdovskyi*, and (in the deeper stations of this zone) *Stylodrilus heringianus* and immature Tubificidae with hair setae (mainly *Tubifex tubifex*, but possibly including *Ilyodrilus templetoni*). The Chironomidae (16% of the population) were again dominated by *Chironomus* and *Cryptochironomus*, but several other species contributed to the total in the deeper part of this zone: *Chironomus* anthracinus-group, *Procladius*, *Kiefferulus*, *Monodiamesa*, and *Potthastia*. *Polypedilum* cf. *scalaenum* was common in this zone on 10 July 1970 but must have emerged from the lake in the intervening months. *Pisidium*, at 21% of the population, comprised a smaller percentage but was more abundant in absolute terms than near the beach. Several species of *Sphaerium* were found. *Pontoporeia* averaged 9% of the population and was present in all samples from this zone; it was more abundant here than in the beach zone, but was still only a minor part of the benthos.

Benthic Zone 2 (16 to 24 m)

The third benthic zone, composed mostly of stations between 1-1/4 to 2-1/2 miles (2-4 km) from shore, was not very different in benthos species from the zone described above except that the numerical fraction due to *Pontoporeia* increased to an average of 26%; *Sphaerium nitidum* at 6% of the population and *Stylodrilus* at 6% of the population also represented increases. The rises in numbers, primarily among these three animals, produced an increase in average total abundance to 5,993 organisms per square meter. *Limnodrilus hoffmeisteri*, *Limnodrilus cervix*, *Aulodrilus* spp., *Chironomus* spp.,

and *Cryptochironomus* sp. 2 decreased in this zone relative to benthic zone 1.

Benthic Zone 3 (more than 24 m)

The deepest part of the survey area was characterized by relative increases in *Pontoporeia* (to 54% of the population) and of *Stylodrilus* (to 16%) and by declining numbers of other species. The average total abundance of benthos was 10,362 organisms per square meter.

Station SDC-7-3

One station (SDC-7-3) stood out from the rest because of its sample size and species composition. This station produced extremely large populations of several species of pollution-tolerant Tubificidae, and many *Procladius* and *Pisidium*. *Procladius* is believed to be a predator on oligochaetes, and is tolerant of organic pollution. The number of total oligochaetes and the large proportion of mature *Limnodrilus cervix* were similar to some samples from the Toledo area of western Lake Erie and far exceeded the abundances of Oligochaeta previously reported from Lake Michigan. This station is not near any major source of pollution, and it is a mystery how such a benthic association could develop. It is considered too anomalous to include in overall averages of benthos in the survey area.

Species Diversity of Benthos

Species diversity indices which combine richness in species with evenness of distribution of individuals among species have recently become established as important tools in the definition of polluted areas in streams (Wilhm and Dorris 1968). Their use is now being extended to preoperational surveys in Lake Michigan (Mozley and Garcia 1972; Beak Consultants, Inc. 1973). If this is to be done rationally, the factors which influence diversity in Lake Michigan

must be considered in some detail. On the basis of November 1970 benthos data, we contend that the interpretation of species diversity measurements will be difficult because of the many biological and environmental factors which influence them.

Species diversities were calculated for the 35 selected samples from the November 1970 survey which were identified to species (Table 5). The formula for species diversity:

$$\bar{d} = -\Sigma \ (N_i/n \log_2 N_i/n)$$

is derived from Shannon and Weaver (1963). Certain conventions were adopted for the calculation of this index. First, the genus *Pisidium* was counted as a single species as it has not yet been sorted into species. Since it is often one of the most numerous taxa, splitting it into species would increase the diversity indices somewhat. Several *Pisidium* species are abundant. Secondly, many Tubificidae cannot be identified to species before they are mature. For calculation of diversity indices we have divided the immatures in each sample or combination of samples in the same proportion as mature Tubificidae to which they could belong. Some species of Oligochaeta, such as *Aulodrilus* spp., *Potamothrix vejdovskyi*, *Peloscolex multisetosus*, and *Stylodrilus heringianus*, can be identified in all stages after the egg, so they were excluded from the apportionment of immatures.

The diversity indices were slightly higher in November 1970 than in July 1970 (Table 10), except near the beach in benthic zone 0. In this zone the chironomids abundant in July were rare or absent in November. In the deeper zones *Pontoporeia* was less abundant and a mixture of Tubificidae and *Pisidium* were more abundant, making the distribution of individuals among different taxa more uniform. The range of diversity indices was again very wide,

Table 10. Ranges and averages of benthos species diversity in the Cook Plant survey area in Julv and November 1970.

Month	Overall average	Maximum	Minimum	Averages by benthic zones			
				Zone 0	Zone 1	Zone 2	Zone 3
July	2.17	3.4	0.9	1.96	2.54	2.23	1.40
November	2.26	3.34	0.65	1.52	2.64	2.43	1.78

including values which in streams would indicate severe pollution (less than 1.0) or very clean water (more than 3.0). Highest diversities, on the average, were in benthic zone 1, which was the richest in taxa. It had 32 total taxa, and an average of 13.6 taxa, compared to 14.1 average but only 27 total taxa in the next most diverse benthic zone, 2. Benthic zone 3 had a total of only 14 taxa, but an average of 9.8 taxa per sample, which illustrates the increase in homogeneity of the fauna in the profundal zone of Lake Michigan. The fewest taxa were in benthic zone 0, which had a total of 10 distinguishable taxa, and an average of 4.2 taxa per sample.

The difference between zones is also related to the dominance of *Pontoporeia*. In benthic zone 1, *Pontoporeia* accounted for only 3.2% of the combined total abundances. Excluding the atypical sample (SDC-7-3) described in the preceding section, *Pontoporeia* made up 8.8% of the total abundance. In zone 2, however, *Pontoporeia* comprised 26% of the total abundance on the average, but was much higher in some samples (Table 6). The diversities in the latter zone consequently tended to be lower. The effect of numerical dominance by *Pontoporeia* on species diversity is illustrated in Figure 7. As its percentage of the total population goes above 30%, the diversity index decreases. The reduction

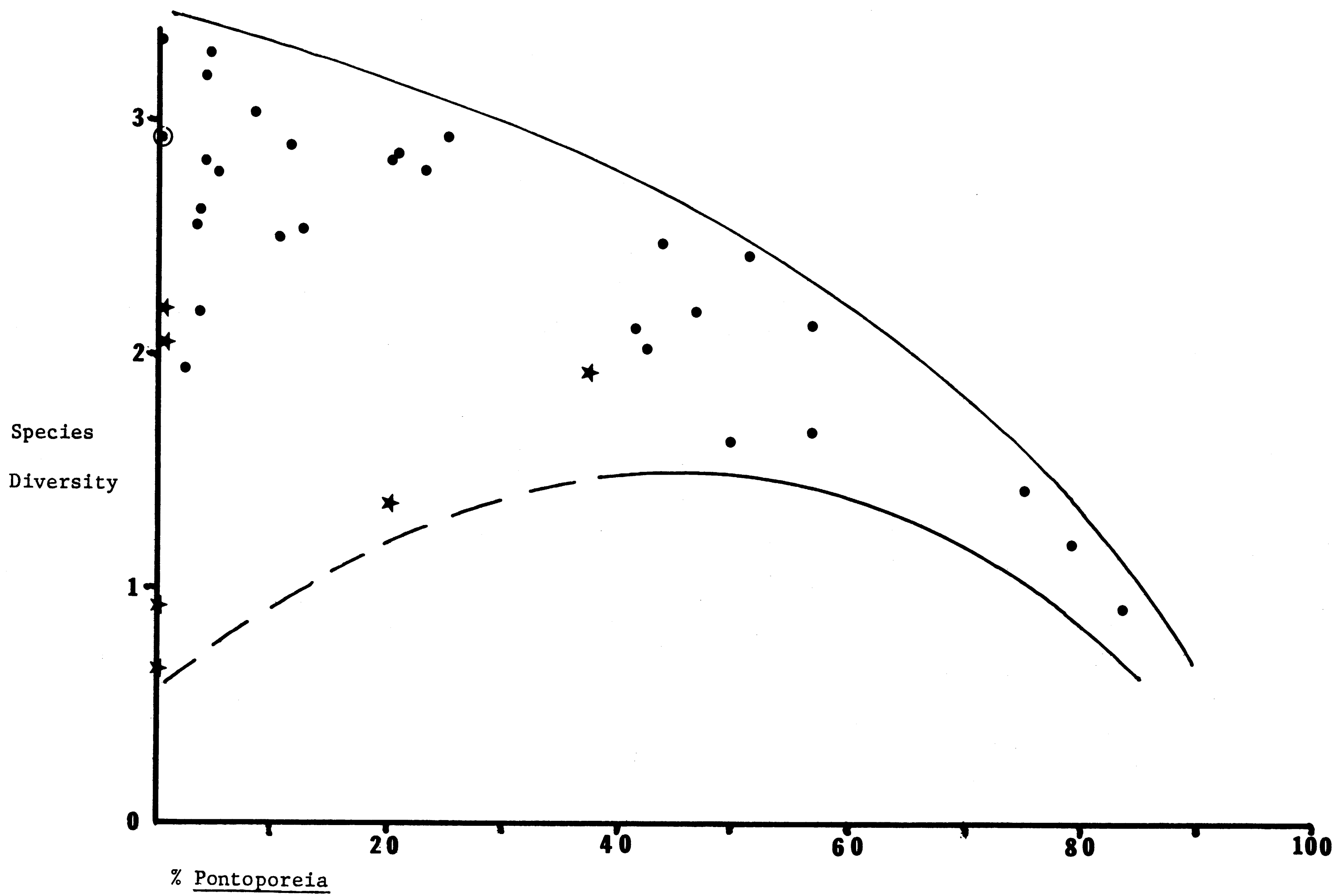

Figure 7. Species diversity versus percent of <u>Pontoporeia affinis</u>. Stars - stations less than 8 m deep. Ringed dot - station SDC-7-3. Solid circles - other stations. The lower envelope border is interrupted to emphasize that low diversities at low percentages of <u>Pontoporeia</u> are due to stations in benthic zone 0. Envelope drawn by eye.

in the index due to the small number of taxa which tolerated the instability of the beach zone is also illustrated there.

Johnson and Brinkhurst (1971) recognized the same effects on species diversity of Lake Ontario benthos, and attributed them to cold water and reduced environmental heterogeneity. A protected warmer embayment, even where it was organically enriched, had higher indices of diversity than the open lake.

In the Great Lakes man's activities could modify species diversity. For instance, unspecified types of pollution are presumed to have reduced the abundance (or at least the dominance) of *Pontoporeia* and increased the abundance of oligochaetes in southern Lake Michigan (Powers and Robertson 1965; USFWPCA 1968). Since the Oligochaeta comprise many species which tend to increase together, pollution could increase species diversity at least initially. The additional habitats offered by intake and outfall structures, breakwalls and other man-made devices increase the diversity of the environment and perhaps that of the population of benthos.

On another tack, the diversity index of a sample is not necessarily representative of the local community. In samples from shallower depth zones (see text above), only half or less of all species present occur in an average sample, and the proportion of taxa in different samples varies widely (Table 5).

It could be argued that rare species, whose effects on this particular diversity index are small (Wilhm and Dorris 1968), cause this discrepancy and therefore their absence from samples should not affect diversity very much. Table 11 gives sets of species diversity indices calculated in various combinations from five samples from the November 1970 collections. The

Table 11. Composite and average species diversities for five stations in the center of the November 1970 survey area. All stations in benthic zone 1 (8-16 meters). Sample codes: 1 = SDC-.5-2; 2 = SDC-.25-1; 3 = NDC-.25-1; 4 = DC-2; 5 = SDC-.5-3.

Number of samples combined	Samples by code	Sums of abundance/m^2	Number of taxa	Ccmposite species diversity	Average species diversity
1	1	1,962	8		2.17
	2	1,116	11		2.49
	3	5,531	21		3.04
	4	2,908	21		3.34
	5	2,908	14		2.92
2	3,5	8,439	22	3.15	2.98
	5,1	4,870	15	2.88	2.55
3	2,4,5	6,932	23	3.38	2.92
	2,3,5	9,555	22	3.11	2.82
4	1,2,3,5	11,517	22	3.02	2.66
	1,2,3,4	11,517	26	3.16	2.76
5	1,2,3,4,5	14,425	27	3.28	2.79

samples all came from stations within a half mile of the central transect of the survey area, and all were from benthic zone 1 where the average sample diversity was highest. The samples were combined in pairs, triplets, etc., by selecting from the five at random using a table of random numbers. Two different combinations were used for each number of combined samples and a composite species diversity index was computed for each combination. For comparison, the simple averages of diversity indices of the individual samples are given for each combination.

The trend towards increasing diversity with larger sample sizes is not very strong, but the composite diversity was always greater than the average

diversity. The composite diversity of all five samples combined is the best representation of the area, but it is not very representative of the diversity to be expected in a single sample. Since five samples in combination produced a diversity which still differed from that of a subset of four of them by almost 0.3 units, even four samples were insufficient to give a precise representation of the local species diversity, and it may be that more than five samples would be necessary. A total of 1,674 animals from 10 casts of the Ponar sampler were identified to produce the data in Table 11. The extension of this amount of effort in only a part of the survey area to achieve a more precise depiction of species diversity over the whole study area is not justifiable.

A less laborious and probably equally precise summarization of species diversity might be obtained by two other measures: the number of species and some measure of dominance of abundant species (Hill 1973). This would also separate the effects of these two factors which interact in less than obvious ways in their effects on the Shannon and Weaver index. The value of possessing diversity information in the Great Lakes remains to be demonstrated.

For the record, diversity indices calculated from our benthos samples are biased toward larger species and the larger individuals of smaller species. Many small chironomids and oligochaetes undoubtably escape through our 0.5-mm sieve while older and larger individuals are retained and counted. Several sorts of organisms which are present in the samples are not represented in the counts because the great majority of them pass through the sieve (e.g. Nematoda, Harpacticoidea, Ostracoda). Therefore, the basis for calculation is not a complete sample of the benthic community and is of value only in comparison to other samples collected in the same way.

The use of low species diversity indices as indicators of pollution must be restricted to streams; it is not applicable to Lake Michigan. The percentages and kinds of individuals comprising the dominant species, and the number of species in different samples are too variable. The reader's attention is called again to Figure 7, wherein diversity indices of 1.67, 1.42, 1.20 and 0.91 were related to 56.6, 76.1, 79.1 and 83.6 percent dominances of the clean-water amphipod *Pontoporeia affinis*, respectively.

The use of diversity indices which are subject to multiple influences of environmental heterogeneity, biological instability and technological error on an arbitrary fraction of the benthic community, in a habitat where there is no dependable theoretical framework for interpreting index values, has no usefulness in judging the condition of the benthic community. In Lake Michigan samples, there may be very few taxa or an overwhelmingly dominating taxon when the index is low; the low index value may indicate either pollution or clean water, depending on what the composition of taxa happens to be. The direction and magnitude of changes in benthos species diversity indices in Lake Michigan cannot be interpreted without concomitant knowledge of the identity of dominant taxa and what their presence indicates about the state of the aquatic environment. There is no strong reason for continuing to calculate this parameter from our benthos sample data.

Judgments of water quality on the basis of benthos information can be made as well from the identity of frequently occurring species in a few taxonomic groups as from the detailed composition of species in all taxa. The Pericarida (Amphipoda and Isopoda), Tubificidae, Chironomidae and a few other aquatic insects are the only groups which have accepted usefulnees for such judgments in the Great Lakes. First priority, therefore, should be

placed on obtaining detailed knowledge of these groups, leaving such problems in species diversity calculation as apportionment of immature Tubificidae, identity of *Pisidium* species, and loss of small specimens in sieving to theoretical studies of community structure.

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Master list of Benthic Macrofauna in the collections of 12 November 1970.

Amphipoda

Pontoporeia affinis

Oligochaeta

Stylodrilus heringianus
Limnodrilus hoffmeisteri
Limnodrilus cervix
Limnodrilus angustipenis
Limnodrilus profundicola
Potamothrix moldaviensis
Potamothrix vejdovskyi
Peloscolex freyi
Peloscolex multisetosus
Tubifex tubifex
Aulodrilus americanus
Aulodrilus pluriseta
Immatures with hair setae
Immatures w/o hair setae

Sphaeriidae

Sphaerium striatinum
Sphaerium nitidum
Sphaerium transversum
Sphaerium sp. 2
Sphaerium sp. 3
Pisidium spp.

Chironomidae

Chironomus anthracinus-group
Chironomus fluviatilis-group
Kiefferulus sp.
Cryptochironomus sp. 2
Cryptochironomus sp. 3

Chironomidae (cont.)

Paracladopelma nereis
Polypedilum cf. *scalaenum*
Tanytarsini spp.
Procladius spp.
Potthastia cf. *longimanus*
Monodiamesa cf. *bathyphila*
Heterotrissocladius cf. *subpilosus*
Heterotrissocladius cf. *grimshawi*

Gastropoda

Lymnaea spp.
Valvata sp.

Hirudinea

Helobdella stagnalis
Helobdella elongata
Glossiphonia complanata
Nephelopsis obscura

Appendix A

PHYSICAL MEASUREMENTS, 12 NOVEMBER 1970

Station	DC-1*	DC-2	DC-3	DC-4	DC-5	DC-6	NDC-.25-1	NDC-.5-1
Time, EST		1638	1616	1602	1753	1821	1648	0951
Wind direction		N	N	N	N	N	N	SE
Wind speed, knts		5	5	5	5	5	5	5
Sea height, ft		1	1	1	1	1	1	0.5
Weather		Overcast	Overcast	Overcast	Overcast	Overcast	Overcast	Light fog
Secchi disc, m		3.5	3.5	4.3			3.0	1.75
Water color			Clear blue-green	Clear blue-green				Milky brownish light green
Surface water temperature, °C		10.2	10.8	10.8	10.2	10.2	10.1	10.0
Water depth, ft		45.5	55.5	66.1	79.0	128.0	45.0	16.8
Bottom type		Fine brown silty sand	Coarse silty brown sand	Silty fine brown sand	Silty fine brown sand	Grey gelatinous clay	Silty fine brown sand	Silty coarse brown sand

* No data, dredges working on the station position.

Appendix A (cont)

Station	NDC-.5-2	NDC-.5-3	NDC-1-1	NDC-1-2	NDC-1-3	NDC-2-1	NDC-2-2	NDC-2-3
Time, EST	1000	1700	0926	0938	1734	0858	0909	1717
Wind direction	SE	N	SE	SE	N	SE	SE	N
Wind speed, knts	5	5	5	5	5	5	5	5
Sea height, ft	0.5	1	0.5	0.5	1	0.5	0.5	1
Weather	Light fog	Overcast	Light fog	Light fog	Overcast	Light fog	Light fog	Overcast
Secchi disc, m	2.2	2.9	2.0	3.0		3.1	2.8	
Water color	Milky brownish light green		Milky brownish green	Milky brownish blue-green		Slightly milky blue-green	Slightly milky blue-green	
Surface water temperature, °C	10.0	10.2	10.0	10.0	10.3	10.5	10.3	10.2
Water depth, ft	30.0	60.0	20.0	29.2	67.0	20.0	30.2	49.7
Bottom type	Silty fine brown sand	Silty fine brown sand	Coarse dark brown silty sand with small gravel	Silty fine light brown sand	Silty fine brown sand	Coarse light brown silty sand	Fine silty light brown sand	1/2 inch silty fine brown sand over soft silty grey clay

Appendix A (cont)

Station	NDC-2-4	NDC-4-1	NDC-4-2	NDC-4-3	NDC-4-4	NDC-7-1	NDC-7-2	NDC-7-3
Time, EST	1935	0815	0832	2000	1902	2132	2122	2109
Wind direction	N	SE	SE	N	N	N	N	N
Wind speed, knts	5	5	5	5	5	10	10	10
Sea height, ft	2	0.5	0.5	2	2	2	2	2
Weather	Overcast	Light fog	Light fog	Overcast	Overcast	Overcast	Overcast	Overcast
Secchi disc, m		2.8	3.0					
Water color		Clear blue-green	Slightly milky blue-green					
Surface water temperature, °C	10.2	10.5	10.5	10.2	10.3	10.2	10.2	10.8
Water depth, ft	79.5	18.6	30.7	60.5	139.0	19.0	27.0	46.5
Bottom type	3/4 inch fine brown silty sand over fine grey silty sand	Coarse silty brown sand	1/2 inch light brown silty sand over silty soft grey clay	Silty fine brown sand	Gelatinous grey clay	Coarse silty brown sand with small gravel	Silty fine brown sand	Silty fine brown sand

Station	NDC-7-4	NDC-7-5	SDC-.25-1	SDC-.5-1	SDC-.5-2	SDC-.5-3	SDC-1-1	SDC-1-2
Time, EST	2055	2032	1628	1016	1025	1546	1037	1046
Wind direction	N	N	N	SE	SE	N	SE	SE
Wind speed, knts	10	10	5	5	5	5	5	5
Sea height, ft	2	2	1	0.5	0.5	0.5	0.5	0.5
Weather	Overcast	Overcast	Overcast	Overcast	Overcast	Overcast	Overcast	Overcast
Secchi disc, m			3.0	1.0	2.3	3.3	2.3	2.5
Water color				Silty light brown	Silty light green	Clear blue-green	Silty light milky green	Milky light green
Surface water temperature, °C	11.5	11.5	10.1	9.6	9.7	10.6	9.8	9.9
Water depth, ft	54.0	76.0	44.0	19.0	32.3	52.0	25.3	31.8
Bottom type	Silty fine brown sand with clay lumps	Silty fine brown sand	Silty fine brown sand	Silty fine brown sand	Silty fine brown sand	Silty fine brown sand	Silty coarse brown sand with gravel	Silty fine brown sand

Appendix A (cont)

Station	SDC-1-3	SDC-2-1	SDC-2-2	SDC-2-3	SDC-2-4	SDC-4-1	SDC-4-2	SDC-4-3
Time, EST	1505	1100	1109	1521	1445	1129	1154	1216
Wind direction	N	SE	SE	N	N	SE	SE	SE
Wind speed, knts	5	5	5	5	5	5	5	5
Sea Height, ft	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Weather	Overcast	Overcast	Overcast	Overcast	Overcast	Overcast	Overcast	Overcast
Secchi disc, m	3.3	3.0	3.1	4.5	5.3	3.0	4.8	6.0
Water color	Clear blue-green	Clear light blue-green	Clear light blue-green	Clear blue-green	Clear blue-green	Clear light blue-green	Clear blue-green	Clear blue-green
Surface water temperature, °C	10.5	9.9	10.0	10.8	11.6	10.0	10.4	11.2
Water depth, ft	64.0	14.8	30.4	53.5	74.6	17.3	29.7	59.5
Bottom type	Silty fine brown sand	Silty brown medium sand	Silty fine brown sand with small clay lumps	1/2 inch silty fine brown sand over silty dark grey sand	1/2 inch silty brown sand over grey sandy clay	Silty brown sand	Silty fine brown sand	Silty fine brown sand with small clay lumps

Appendix A (cont)

Station	SDC-4-4	SDC-7-1	SDC-7-2	SDC-7-3	SDC-7-4	SDC-7-5
Time, EST	1413	1245	1300	1312	1326	1344
Wind direction	SE	SE	SE	SE	SE	SE
Wind speed, knts	5	5	5	5	5	5
Sea height, ft	0.5	0.5	0.5	0.5	0.5	0.5
Weather	Partly cloudy	Overcast	Overcast	Clearing	Clearing	Partly cloudy
Secchi disc, m	5.5	3.3	3.5	5.3	5.8	6.0
Water color	Clear blue-green	Clear light blue-green	Clear light blue-green	Clear blue-green	Clear blue-green	Clear blue-green
Surface water temperature, °C	11.5	11.0	11.0	11.0	11.2	12.0
Water depth, ft	106.5	20.2	30.0	50.6	55.1	70.5
Bottom type	Slightly sandy gelatinous grey clay	Silty brown sand	Silty fine brown sand	Sandy silty gelatinous grey clay	Silty fine brown sand	3/4 inch silty soft grey clay over fine brown sand